NDCX-II Application to VNL and User HEDLP

Frank Bieniosek
LBNL

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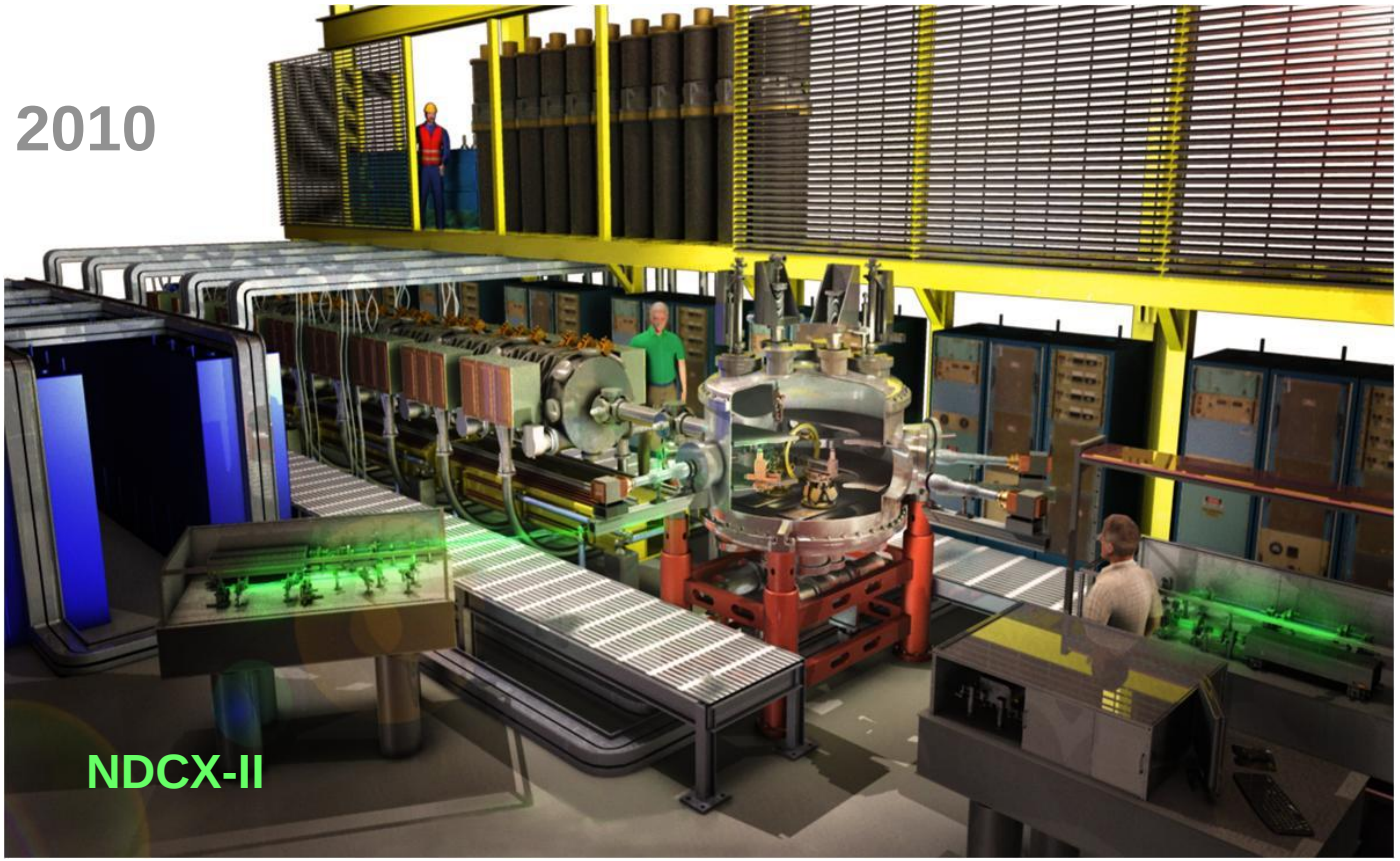

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Overview of HIFS-VNL target experiment program

•We have recently held a workshop on ion beam driven HEDP.
-2010 Ion Beam Driven High Energy Density Workshop, June 22-24, 2010
http://hifweb.lbl.gov/public/BeamHEDP2010/Presentations.html

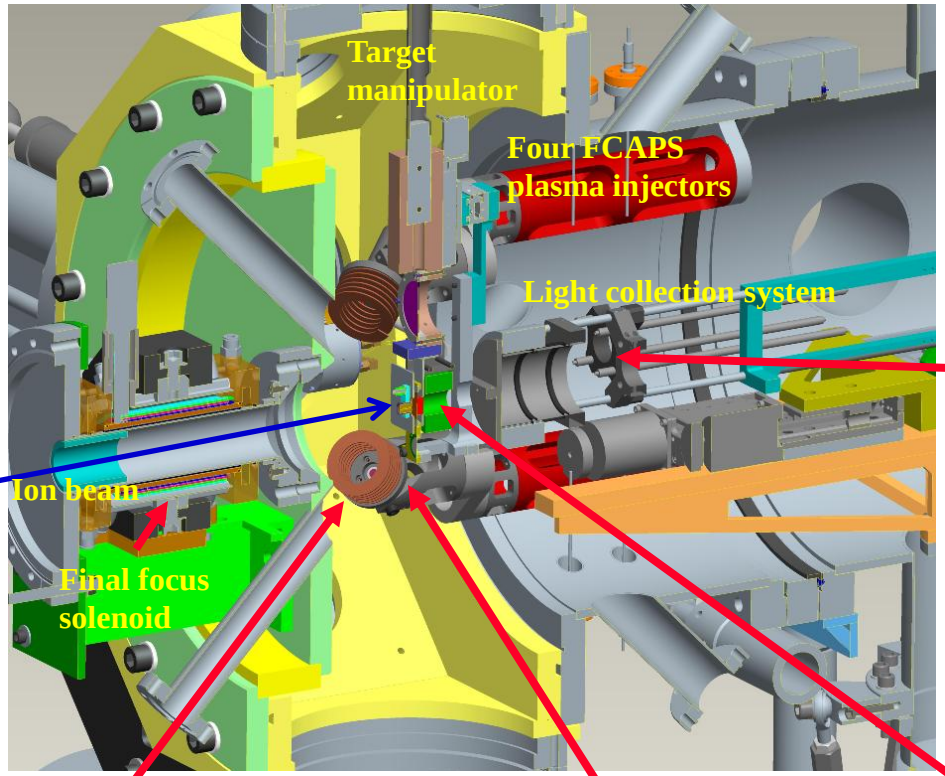
•NDCX-I (0.3-MeV K^+), to be operated into 2011 as a test bed for beam manipulation, target physics and diagnostic development.

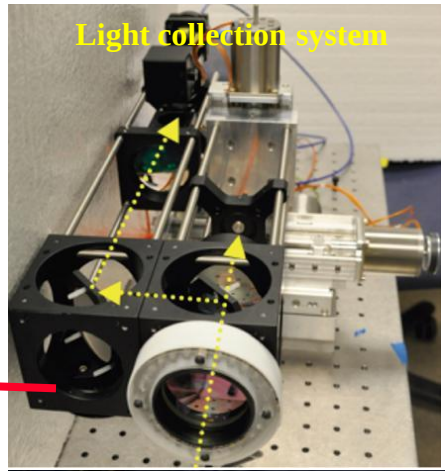
•NDCX-II (1-3 MeV Li^+)
-Experimental program to migrate to NDCX-II after beam commissioning (2012).
-Uniform heating of mm volumes, T = 1-3 eV, <1 ns pulse
-A user facility with an extensive set of diagnostics

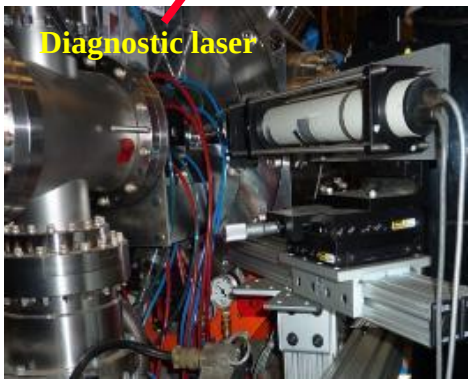
•New target chamber with enhanced capability for diagnostics to be designed for installation on NDCX-II; *e.g.* high power lasers, cryo-targets, x-ray diagnostics.

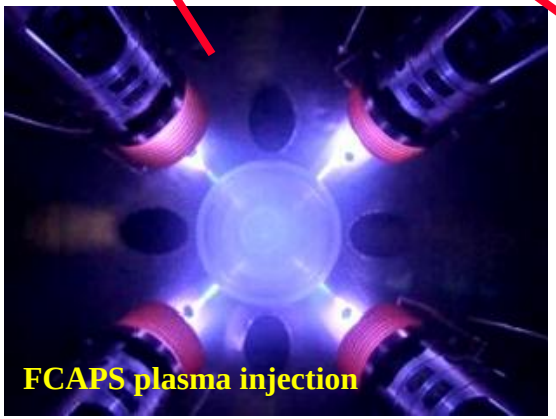
•This presentation focuses on plans for VNL and user target chamber HEDP and HIFS-related experiments on NDCX-II.

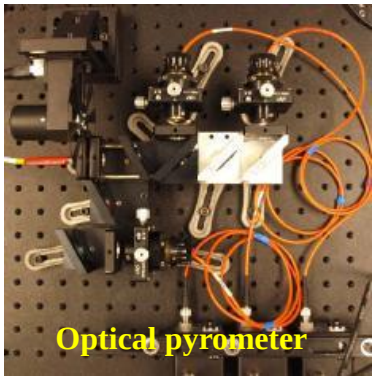
Initial operation of NDCX-II will utilize the existing NDCX-I target chamber and final focus solenoid.











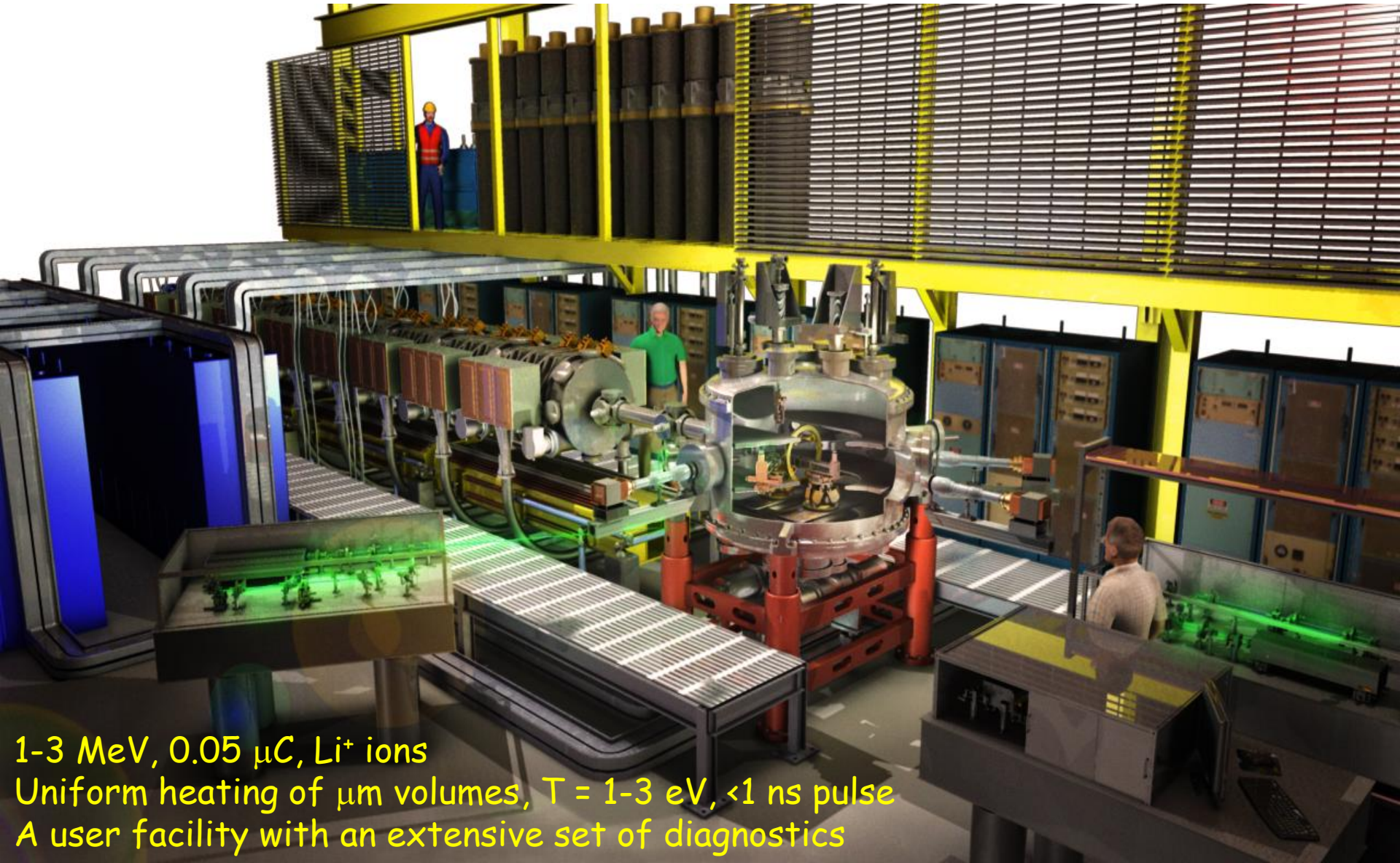
Target diagnostics have been developed on NDCX-I, and will be available for transfer to NDCX-II.

Existing diagnostics	parameters measured
• IR Photodiode	IR thermal emission: T (<3000 K)
• Streak camera + spectrometer	T (>3000 K), spectral emission lines
• Fast multi-channel pyrometer	T (sub-ns response)
• 2 ICCD (PIMAX) cameras	imaging beam spot, target evolution
• Laser transmission	target breakup
• Beam current transformer	beam transmission through target
• Transmitted beam radiography	ion stopping, scattering
• Tungsten calorimeter	beam intensity on target
• Scintillators	beam intensity profile
• Fast Faraday cup	beam current pulse (~ns response)

Near term diagnostics under development

• Polarimetry	surface roughness, improved pyrometer
• VISAR	target surface motion

NDCX-II Warm Dense Matter Research Facility is under construction (completion 2012).



1-3 MeV, 0.05 μC, Li^+ ions
Uniform heating of μm volumes, T = 1-3 eV, <1 ns pulse
A user facility with an extensive set of diagnostics

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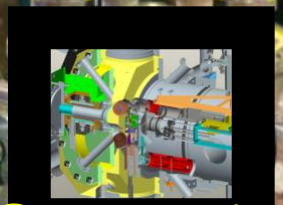


Existing NDCX-I target chamber

1-3 MeV, 0.05 μC, Li^+ ions
Uniform heating of μm volumes, T = 1-3 eV, <1 ns pulse
A user facility with an extensive set of diagnostics

NDCX-II will provide an exciting facility for beam-driven high energy density and IFE target physics

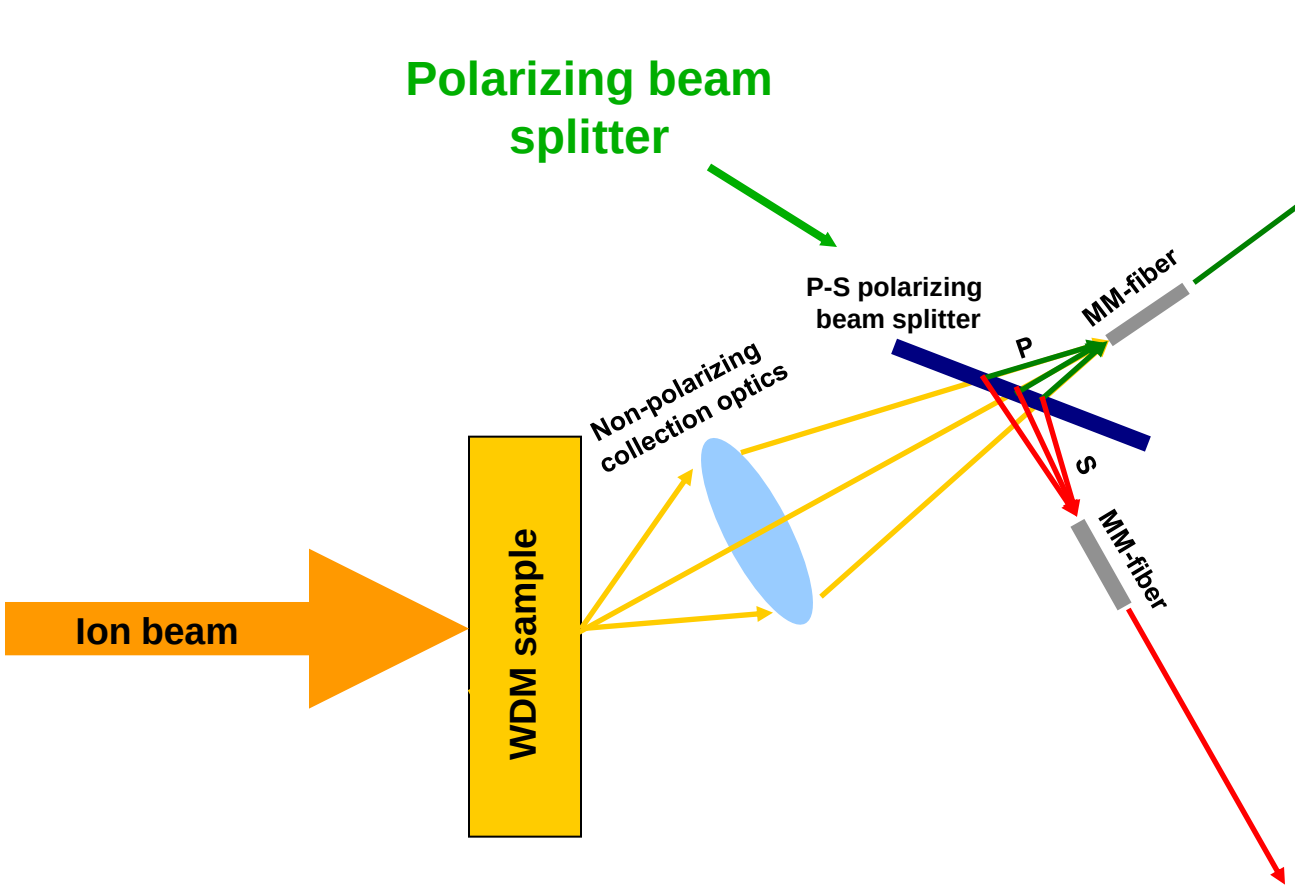
- Increased beam intensity >100x (~10^{10} W/cm^2) at final focus, shortened pulse (sub-ns) and longer ion range (~10x) in NDCX-II will greatly increase experimental capabilities to study WDM (~7-10 kJ/g in Al). Possible experiments include:

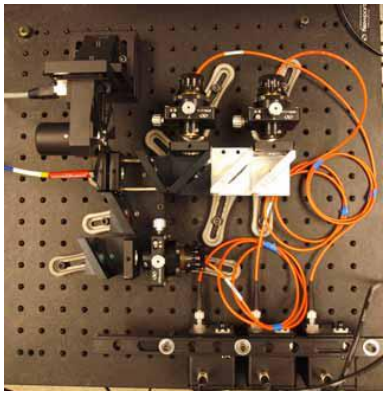
- Continue experiments from NDCX-I: e.g. diagnostic development, transient darkening, beam stopping/scattering
- Ion beam dynamics, incl. compression and space-charge neutralized final focus
- Phase transitions, esp. liquid-gas interface, critical point, EOS
- Porous targets
- Positive/negative ion targets
- Shock wave and other studies related to IFE
- Shock physics related to WDM
- Cylindrical/spherical bubble implosions
- Final focus upgrades (see talk by A. Friedman)
  - Plasma lens, high field solenoid, self-focusing (Dorf pinch), etc.

We have a number of interested collaborators.

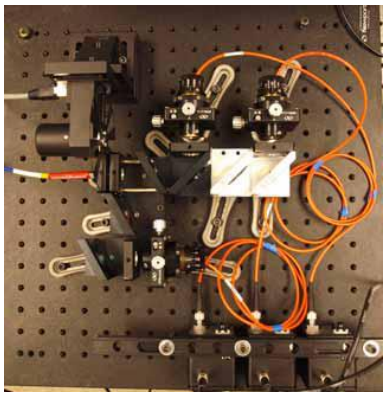
- **Andrew Ng, UBC, Specific heat, shock experiments**
- **Toru Sasaki, Nagaoka U., x-ray backlighting**
- **Hitoki Yoneda, UEC Tokyo, optical properties of WDM**
- Dave Eder, LLNL, NIF target holder
- Andrew Forsman, GA, laser diagnostics
- Phil Heimann, LBNL, pyrometer diagnostic of laser-heated target at ALS
- Dick Lee, LLNL, WDM isochoric heating
- Tim Renk, Sandia, ion beam effects on materials
- Markus Roth, TU Darmstadt
- *Alice Koniges, WDM modeling (ALE-AMR) to include surface tension effects*
- *Richard More, WDM theory*
- *Roberto Piriz, U Castilla-La Mancha, Spain, shock modeling*
- *Naeem Tahir, GSI, shock modeling*
- *Seth Veitzer, Tech-X, cone focusing*
- *Jonathan Wurtele, UC Berkeley, simulations and theory*
- *Simon Yu, Chinese U. of Hong Kong, bubble collapse, ion coupling to shocks*

Polarization pyrometer may dramatically improve accuracy of optical pyrometry temperature measurement.



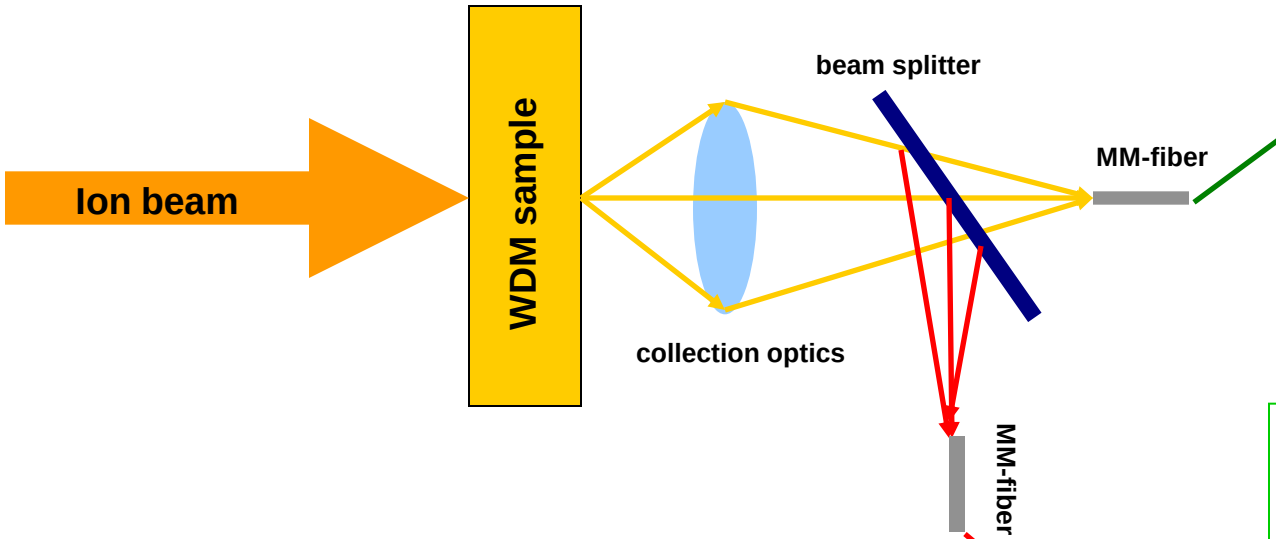


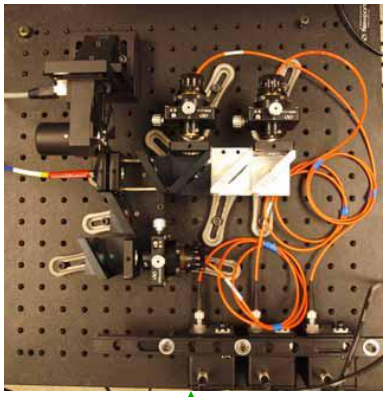
Existing 4-channel pyrometer: measure at two angles.



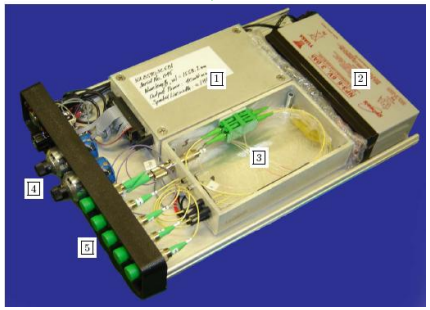
Conventional pyrometer is underdetermined – addition of polarization information provides independent way to determine emissivity.

Multiple-wavelength optical pyrometry/velocity interferometry for EOS studies.





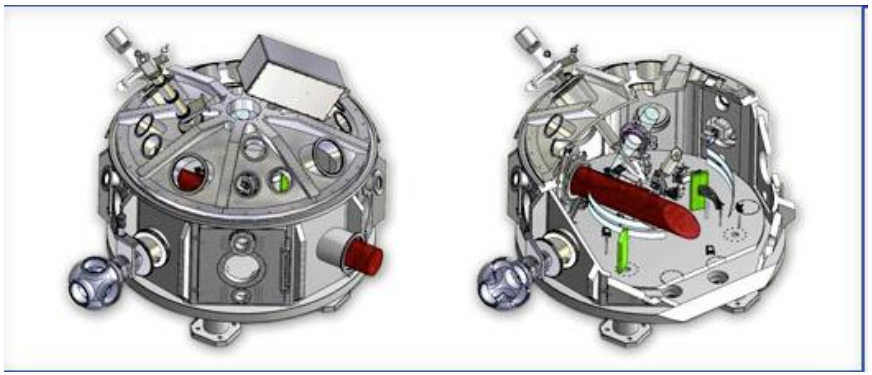
Extend existing pyrometer and VISAR to cover 150-1500 nm



Different wavelengths probe different critical densities in the expanding target. Evolution of velocity and brightness temperatures can be compared with EOS model predictions.

Diagnostic and target station development in NDCX-II, and long term (IB-HEDPX).

- Target and diagnostics modeled after LCLS MEC user area ~$20 million.



(Titan target chamber)

- Polarimetry: view target at off normal angle
- Cryo-target capability
- X-ray diagnostics
- X-ray Thomson scattering
- Beam and accelerator diagnostics
- Laser-based diagnostics
- High-power laser systems, e.g. driving shocks
- Final focus upgrades and enhanced plasma neutralization

VNL base program funding increase to take over facility operation in FY12.

- NDCX-II project budget ($11 M) covers minimal beam diagnostics, no commissioning
  - Requires transfer of final focus solenoid, target chamber, and target diagnostics
  - Does not allow for simultaneous operation of NDCX-I and NDCX-II

- User group can improve experimental utilization and effectiveness

- Increased DOE support in FY11-15 (in WAS)
  - Commissioning & operation
    - Facility
    - Diagnostics
    - Targets & target chamber
    - Computation & theory support
  - Tech support
  - User support

- Program funds ramp up needed to
  - Operate NDCX-I/II
  - Hire new staff (post-doc/students)

	Comm. & ops.	Tech supt.	User supt.	
FY	**$M**			**Total**
11	**0**	**0**	**1**	**1**
12	**4**	**1**	**2**	**7**
13	**4**	**1**	**3**	**8**
14	**4**	**1**	**3**	**8**
15	**4**	**1**	**3**	**8**

Budget numbers from NDCX-II WAS

Summary

- NDCX-I provides a test bed for target physics studies, target diagnostics development, and ion beam compression studies.
- Experimental and diagnostic capability have been developed in experiments studying target evolution and droplet formation. These will be readily transferred to NDCX-II, which will have much greater capability than NDCX-I.
- Future experiments with NDCX-I and NDCX-II will explore aspects of HEDP and HIFS physics including beam manipulation, high electron affinity targets, beam-target coupling, etc.
- We encourage participation in the experiments to increase productivity of the facility, including development of new diagnostics.

Extra slides

Some Recent Related Publications

- **J.J. Barnard, et al., Simulations for experimental study of warm dense matter and inertial fusion energy applications on NDCX-II, IFSA 2009, J. Phys.: Conf. Ser. 244 032027, 2010.**
- **F.M. Bieniosek, et al., Ion-beam-driven warm dense matter experiments, IFSA2009, J. Phys.: Conf. Ser. 244 032028, 2010.**
- **F. M. Bieniosek, E. Henestroza, S. Lidia, P. A. Ni, Diagnostics for ion beam driven high energy density physics experiments, Rev. Sci. Instrum. 81, 10E112 (2010)**
- **F.M. Bieniosek, E. Henestroza, P. Ni, Funnel cone for focusing intense ion beams on a target, Laser and Particle Beams (2010) 28, 209-214.**
- **S M Lidia, F M Bieniosek, P Ni, P Seidl, Final focus ion beam intensity from tungsten foil calorimeter and scintillator in NDCX-I, Proc. 2010 Beam Instrumentation Workshop, Santa Fe, NM, USA**
- **R More, M Goto, F Graziani, P Ni, H Yoneda, Emission of visible light by hot dense metals, Plasma and Fusion Research 5, S2008 (2010).**
- **F.M. Bieniosek, et al., High energy density physics experiments with intense heavy ion beams, Nucl. Instrum. Meth. A 606 (2009) 146-151.**
- **S.M. Lidia, et. al., Commissioning Results of the Upgraded Neutralized Drift Compression Experiment, PAC09, Vancouver Canada, May 4-8, 2009, LBNL-1842E.**
- **P.A. Seidl, et al., Progress in beam focusing and compression for warm-dense-matter experiments, Nucl. Instrum. Meth. A 606 (2009) 75-82.**
- **W.L. Waldron, et al., Plans for Warm Dense Matter and IFE Target Experiments on NDCX-II, Fusion Sci. Technol., 56, 452-455, (2009).**

Examples of interested collaborators

- **Hitoki Yoneda - has performed experiments at LBNL on optical properties of WDM ("black glass"); requested beam time on NDCX-I using optical fiber as target**

- **Andrew Ng – interested in shock experiments on NDCX-II, has requested beam time on NDCX-I to study specific heat of targets under fast beam heating.**

- **Toru Sasaki – proposed building and installing a compact x-ray backlighter for NDCX-I and NDCX-II targets**

- **Alice Koniges – developed a code for WDM modeling (ALE-AMR), to include surface tension effects, relevant to NDCX-I data suggesting importance of surface tension in target response to volumetric beam heating**